MRI Safe Electrodes for Spinal Cord Stimulation (SCS)

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Introduction

A lead attached to an implant can act as a resonator in an MRI machine. In previous work, we have shown that the worst-case heating of a single-core lead results from strong E-field at the distal end for certain particular lengths. Figure 1 compares simulated worst-case exposure with measured data points obtained in a phantom torso placed in a 3-Tesla MRI machine as function of lead length. We present here further evidence [9] that multi-filar leads spread energy captured from RF fields between filars. We describe how decoy filars and decoy electrodes connected to decoy filars can convey the majority of intercepted energy into human tissue in a distributed fashion.

Methods

Temperature rise around a straight, single filar (Figure 1) has been computed using COMSOL Multiphysics 4.4 and simulation results have been validated by comparison with measurements taken in a 3-Tesla MRI machine (Figure 1). Worst case local SAR values for a twelve filar (electrode) spinal cord stimulator lead in a saline solution (Base Case) have been computed using ANSYS EM Design Suite (HFSS). Then, decoy filars and decoy electrodes have been added to the Base Case (Base Case plus Decoy). The simulation results are presented in Figures 2 and 3.

Results

A single filar lead exposed to an RF field at 128 MHz has an exposure-vs-length function that peaks at a length of about 200 mm. Multi-filar leads show worst-case local SAR values around one particular electrode (Figure 2). Adding decoy filars and non-therapeutic decoy electrodes to therapeutic filars can divert and dissipate a significant fraction of captured RF energy in a distributed way along the lead (Figure 3). Simulated worst case local SAR values have been reduced by a factor of ten for lead lengths ranging from 200 mm to 1200 mm.

Discussion

RF energy is coupled between filars within multi-filar leads. Filars show critical lengths where they capture the majority of the RF energy and may present a risk. Adding decoy filars to therapeutic filars and non-therapeutic decoy electrodes may deflect enough energy to deliver safe operation.

Conclusions

These results promise the possibility of designing multi-wire leads that are unconditionally safe in whole-body MRI scanners. This may require appropriate decoy filars, non-therapeutic decoy electrodes and a distributed release of captured RF energy into human tissue.

Acknowledgement

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Figures

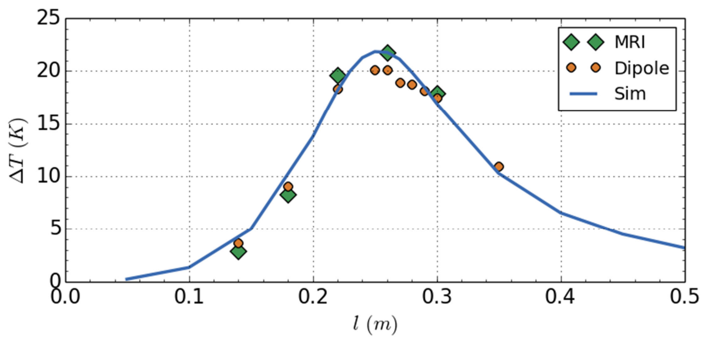


Figure 1 - Simulated and measured temperature rise T near the distal electrode of an insulated wire after 5 minutes in a 3T MRI machine. Measurements from the dipole test method yield a similar profile.

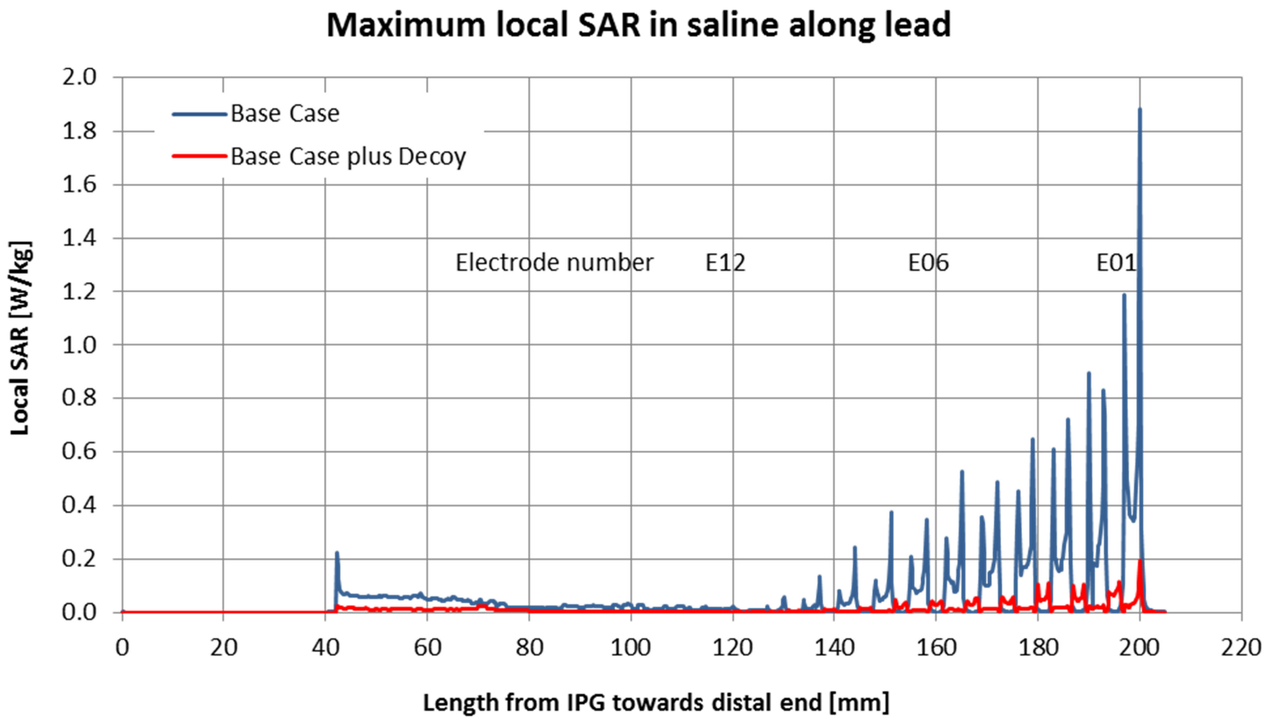
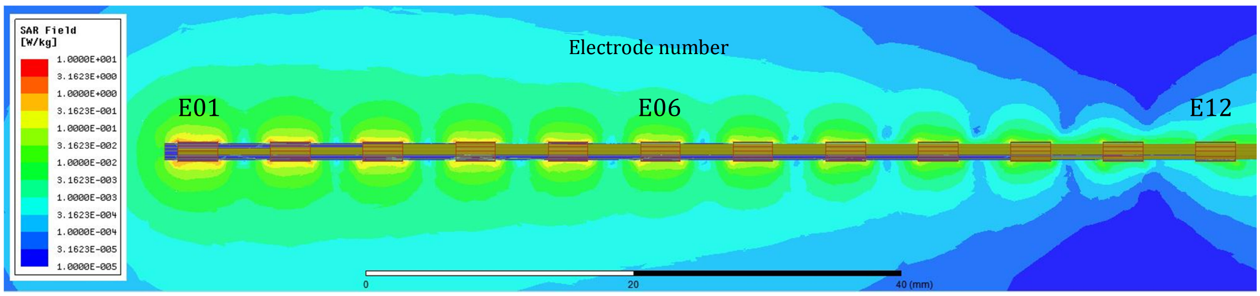


Figure 2 - Local SAR in saline solution normalised to 1 V/m of the exciting electrical field for a spinal cord stimulator with 12 electrodes at the distal end and for a worst case lead length of 200 mm



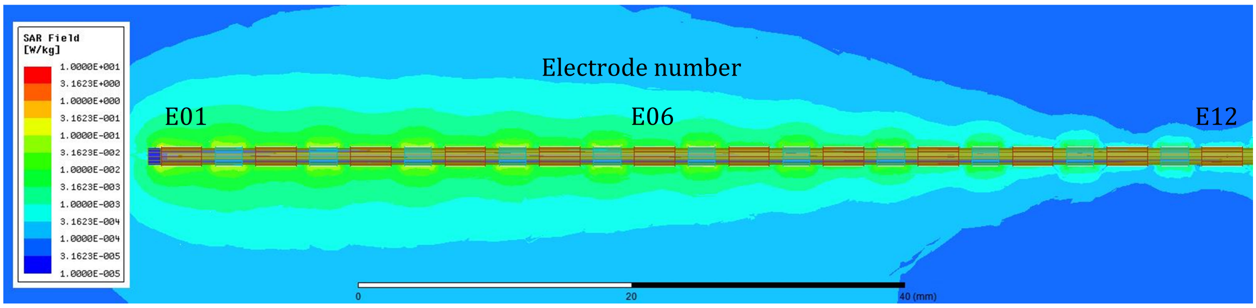


Figure 3 - Local SAR distribution in saline solution normalised to 1 V/m of the exciting electrical field for a spinal cord stimulator with 12 electrodes at the distal end and for a worst case lead length of 200 mm.

Top	Base Case
Bottom	Base Case plus Decoy

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